A DATA FUSION APPROACH FOR THE ANALYSIS OF AZIMUTH AMBIGUITIES

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ABSTRACT

In the context of sea and ocean monitoring from SAR images, this paper illustrates a study of azimuth ambiguities, together with a new approach suggested to solve the problem.

The proposed method presents here the added value in application to coastal monitoring and ship detection.

This work is developed in the context of the project1 funded by the Italian Space Agency. The data set for experimentation is made of COSMO-SkyMed images related to Ligurian Sea (Italy).

Index Terms— Sea monitoring, Data Fusion, Cosmo-Skymed.

1. INTRODUCTION

The sampling of the Doppler spectrum at finite intervals of the Pulse Repetition Frequency (PRF) causes Doppler ambiguities. While the system is usually designed to avoid range ambiguities, the azimuth ambiguities become visible especially in low backscattering area, such as the ocean surface in low wind speed conditions.

Frequencies higher than the PRF are folded into the azimuth spectrum causing aliasing. The spatial displacement of an azimuth ambiguity to the actual target is related to the radar system parameters [1] by the following equation:

\[
\Delta x = \frac{n f_{PRF} V_a}{f_{dr}}
\]  

(1)

where \( n \) is the ambiguity index, \( f_{PRF} \) is the Pulse Repetition Frequency [4], \( V_a \) is the platform’s velocity and \( f_{dr} \) is the Doppler rate [5].

When cross-polarization is not available, some other approaches have been developed to address ambiguities problems [6] [7].

The authors propose here an innovative approach to this purpose, based on the overlapping of the original and translated image in order to enhance the correspondence between target and the related ambiguity.

A data-fusion image, achieved through an appropriate association of color channel to the original and the translated copy, allows a fast discrimination between real targets and ambiguity spots.

In addition to help general recognition systems in the sea and near the coastline, the proposed method is very useful in the discrimination of false positive alarms during ship detection.

2. GENERAL OVERVIEW

For the experiments, a data set based on acquisitions in Stripmap mode by Cosmo-Skymed (CSK) satellite have been used, obtained from the ASI Project ”Development of Imaging and Monitoring Methodologies based on the use of COSMO/Skymed SAR Data” (ID 2246).

The CSK Stripmap, acquired in HIMAGE mode, achieving medium resolution, wide swath imaging, with swath extension 40 km and spatial resolution of 3x3 m² single look, on February 20, 2011 over the Ligurian coast, shows some of these effects (Fig. 1).

Few of them derive from strong point targets like ships; while most of them are due to cities and man-made structures over land. Ships and azimuth ambiguities have Normalized Radar Cross-Section (NRCS) of the same order of magnitude and therefore the only radar backscatter is not enough to discard false ship positive due to ambiguity.

3. PROPOSED METHOD

The most evident case, in the acquired CSK image, is the one related to the harbor wharf located in Vado Ligure, near Savona city. At an azimuth distance of about 5.5 km, the ambiguity effect is clearly visible, as pointed out by Fig. 2 where
Fig. 1. CSK Stripmap image acquired on February 20, 2011, over the Ligurian coast.

The bright spots placed in the red window of Fig. 1 are zoomed in Fig. 3, right side. As one can notice, their displacement give them in good correlation with the city area shown in Fig. 3, left side. The maximum correlation between the original image and its translated version gives the exact displacement value that must be applied to realize a visual enhancement of the ambiguities and a subsequent processing useful for disambiguation.

Fig. 2. Vado Ligure wharf (left); related azimuth ambiguity (right).

By following the approach proposed in [3] and by means of an appropriate association of data and RGB color channels, the fast-ready display shown in Fig. 4 is achieved.

Fig. 3. Zoom of red window in fig.1: the town of Savona (left); related azimuth ambiguities (right).

Starting from the evaluation of the approximate distance between original artefacts and their ambiguities, given by equation (1), the exact number of pixels is calculated and a copy of the original image translated in the azimuth direction is generated. The R and the G channels are associated to such an image. The B channel is associated to the original image. As a result, ambiguities pixels that are in good relationship with the related target appear in white. Blue pixels are strong scatterers and they do not generate ambiguities. Yellow pixels are associated to low correlation since they derive from real targets in the sea, whose actual position can be estimated by replacing pixels to their original site.

Fig. 4. Color data fusion of the original SAR image of Fig. 1 and its displaced copy.
3.1. Man-made structures

As one can see in the details reported in Fig. 5, the Vado Ligure wharf has many white spots proving the good correspondence between the structure and its ghost image.

![Fig. 5. Details from Fig. 4: Vado wharf.](image)

The blue points have not given rise to any targets in the lower image sea region. Even more evident are the white spots in the composition referring to the town of Savona, as shown in Fig. 6.

![Fig. 6. Details from Fig. 4: Savona town.](image)

3.2. Ship detection

Independently of the ship detection method, some efforts must be spent in the analysis of azimuth ambiguities as a post-processing step to discard false positive results that are due to ambiguities. The displacement of two detected targets might suggest the presence of an azimuth ambiguity, thus solving the false alarm.

Referring to Fig. 7, the lowermost target was not overlapped with any displaced spot, therefore we can understand that it is associated to a real target that did not give rise to any ambiguity. On the contrary, the upper spot is a ship overlapped with an ambiguity, then attention must be paid to solve such an error. The same method was applied to some ships or ship-like spots.

![Fig. 7. Spatial correlation color composition with ships and ambiguities.](image)

4. CONCLUSION

In this paper a new approach has been proposed to detect the azimuth ambiguities in remote sensing radar images. The detection is achieved by using a method based on the calculation of spatial displacement, coupled with an appropriate association of data and RGB color channels. In general, the proposed approach seems to be effective also in man-made structure detection in addition to different applications like ship detection.

The obtained results show that the proposed approach is able to discard azimuth ambiguities in a fast way encouraging the use of high resolution X-band SAR data for detection purposes of artificial structures and ships.

5. REFERENCES


